

## ELECTRONIC DEVICES WITH DIRECTIONAL HAPTIC OUTPUT

[0001] This application is a continuation of patent application Ser. No. 15/988,936, filed May 24, 2018, which claims the benefit of provisional patent application No. 62/535,166, filed Jul. 20, 2017, both of which are hereby incorporated by reference herein in their entireties.

### FIELD

[0002] This relates generally to electronic equipment, and, more particularly, to electronic equipment that supplies haptic output.

### BACKGROUND

[0003] Devices such as wearable devices sometimes incorporate haptic output components. Haptic output components may supply a user with haptic output while the user is interacting with software such as gaming software.

[0004] It can be challenging to design a haptic output device. If care is not taken, haptic output may be too weak or may not provide a desired sensation for a user, haptic output may not be applied to an appropriate location on the body of a user, or a haptic output device may be overly bulky or difficult to use.

### SUMMARY

[0005] A system may have one or more electronic devices for gathering input and providing output to a user. In configurations with multiple devices, the devices may communicate wirelessly. One device may be used as a controller for another device. In a single-device system, user input and output may be handled by the same device.

[0006] To gather user input, devices may include user input sensors such as force sensors, touch sensors, motion sensors, and other input devices. The user input that is gathered may be used to manipulate objects in a virtual world or to interact with other content being provided to a user.

[0007] To provide a user with output, devices may have visual output devices, audio output components, and haptic output components. For example, a head-mounted device may have a display for presenting virtual reality or mixed reality content to a user.

[0008] Haptic output components may be used to apply an apparent force in a given direction relative to a device housing surface such as a housing sidewall surface or other device surface. Control circuitry in a device may direct a haptic output component to produce the apparent applied force perpendicular to the surface or tangential to the housing surface. The apparent applied force may be provided as feedback while the control circuitry is directing a display in the device or in an external device to provide a user with visual content based on the user input. By adjusting the direction of the apparent applied force, a user may be provided with sensations such as increased or decreased weight, increased or decreased lateral force, friction (resistance to finger movement in a particular direction), slippage (finger movement assistance), rendered boundary effects, and/or other directional haptic effects.

### BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1 is a perspective view of an illustrative electronic device in accordance with an embodiment.

[0010] FIG. 2 is a cross-sectional side view of the illustrative electronic device of FIG. 1 in accordance with an embodiment.

[0011] FIG. 3 is a cross-sectional side view of an illustrative haptic output component with a central deflecting portion in accordance with an embodiment.

[0012] FIG. 4 is a cross-sectional side view of an illustrative deflecting beam haptic output component in accordance with an embodiment.

[0013] FIG. 5 is a cross-sectional side view of an illustrative haptic output component based on a stack of haptic output structures in accordance with an embodiment.

[0014] FIG. 6 is a side view of an illustrative voice coil haptic output component in accordance with an embodiment.

[0015] FIG. 7 is a cross-sectional side view of an illustrative linear resonance actuator haptic output component in accordance with an embodiment.

[0016] FIG. 8 is a side view of an illustrative haptic output component with a portion that extends when actuated in accordance with an embodiment.

[0017] FIG. 9 is a schematic diagram of an illustrative electronic device in accordance with an embodiment.

[0018] FIG. 10 is a cross-sectional side view of an illustrative electronic device mounted on a finger in accordance with an embodiment.

[0019] FIG. 11 is a cross-sectional side view of an illustrative wristwatch device in accordance with an embodiment.

[0020] FIG. 12 is a side view of an illustrative head-mounted device in accordance with an embodiment.

[0021] FIG. 13 is a cross-sectional side view of an illustrative haptic output device that may apply shear force to a user's finger or other external object in accordance with an embodiment.

[0022] FIGS. 14, 15, 16, 17, and 18 are graphs of illustrative haptic output drive signals in accordance with embodiments.

[0023] FIG. 19 is a diagram showing how an electronic device may be used to control the position of an object on a display while providing haptic feedback to a user of the device in accordance with an embodiment.

### DETAILED DESCRIPTION

[0024] A system may include one or more electronic devices. The electronic devices may be used to gather input from a user. In some configurations, a first electronic device may be used to control a second electronic device. For example, a first electronic device may serve as an input-output device for a second electronic device. Haptic output components may be included in the electronic devices to provide a user with haptic output.

[0025] FIG. 1 is a perspective view of an illustrative electronic device. Electronic device 10 may be a computing device such as a laptop computer, a computer monitor containing an embedded computer, a tablet computer, a cellular telephone, a media player, or other handheld or portable electronic device, a smaller device such as a wristwatch device, a pendant device, a headphone or earpiece device, a device embedded in eyeglasses or other head-